GJ

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ENCH 501: Transport Phenomena Quiz #1 September 21, 2010

Time Allowed: 35 mins. Name:

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1. (6 points)

A laboratory-scale mixer is operated to separate bitumen from oil sands. Hot water (about 85°C), caustic soda and oil sands are charged into the reactor and the slurry is agitated continuously until a uniform suspension is formed. Then the agitation is stopped and the components allowed to separate by gravity - oil to the top and sand grains to the bottom.

In the experiments, it was discovered that the degree of mixing and ease of phase separation depend on the power input (P, rate of work), the velocity of the tip of the propeller (U), the density and viscosity of the liquid medium (ρ_L, μ), the difference between the densities of sand particles and oil droplets ($\rho_S - \rho_O$), the diameter of the propeller (d) and the diameter of the tank (D).

Determine the dimensionless groups required to scale up the mixer. Show all important steps.

2. (4 points)

Attached is an image of a "mariner weather glass" in use for centuries to predict weather. The glass is filled with colored water and attached to a wall , out of sunlight and away from heaters to avoid false readings.

Explain, as much as possible, how the device works to forecast weather.

ENCH 501 Quiz 1 Solution Sept 21, 2010

(a) $P = f(u, \rho_L, \rho_s - \rho_0, \mu, d, D)$

Power or Energy / time	$\frac{m}{s}$	$\frac{kg}{m^3}$	$\frac{kg}{m^3}$	$Pa.s = \frac{N\,s}{m^2} = \frac{kg\,m}{s^2}\frac{s}{m^2} = \frac{kg/s}{m\,s}$	m	m	← Units
$\frac{J}{s} = \frac{N.m}{s} = \frac{kg\,m^2}{s^3}$							
$\frac{ML^2}{t^3}$	L	$\frac{M}{L^3}$	$\frac{M}{L^3}$	$\frac{M}{Lt}$	L	L	← Dimensions

This problem has 3 dimensions – M, L, t

There are 7 dimensional variables, ∴ 4 dimensionless groups can be formed. Two of these are immediately obvious – $\frac{\rho_s - \rho_0}{\rho_L}$ and $\frac{d}{D}$

Hence reduce the function for P to

$P = g(u, \rho_L, \mu, D)$ – by dropping 2 of the variables since we know two of the groups.

Select 3 variables as repeating – u, ρ, D

$$\therefore \quad \Pi_1 = u^a \rho^b D^c \mu^d$$
$$\Pi_2 = u^{a'} \rho^{b'} D^{c'} P^{d'}$$

Substitute dimensions

$$\Pi_1 = \left[\frac{L}{t}\right]^a \left[\frac{M}{L^3}\right]^b \left[L\right]^c \left[\frac{M}{Lt}\right]^d = [M]^0 [L]^0 [t]^0$$

Solve

$M - \quad 0 = b + d$

$L - \quad 0 = a - 3b + c - d$

$t - \quad 0 = -a - d$

$\therefore \quad b = -d, \quad a = -d, \quad c = -d$

$\therefore \quad \Pi_1 = \left(\frac{u\rho D}{\mu}\right)^d$ — dimensionless gp in brackets
↳ Reynolds

Similar process for Π_2

$M - \quad 0 = b' + d'$

$L - \quad 0 = a' - 3b' + c' + 2d'$

$t - \quad 0 = -a' - 3d'$

$\therefore \quad b = -d, \quad a = -3d, \quad c = -2d$

$\Pi_2 = \left(\frac{P}{\rho_L D^2 u^3}\right)^d$ — dimensionless gp - Power number

$$\therefore \quad \frac{P}{\rho_L D^2 u^3} = f\left(\frac{u\rho_L D}{\mu}, \frac{d}{D}, \frac{\rho_s - \rho_o}{\rho_L}\right)$$

are the dimensionless groups.

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Note:
Students may obtain other dimensionless groups from above, and they would be equally valid.

2. Weather patterns are produced by air flow patterns, moisture content of the atmosphere and daily heating - cooling cycles. These factors affect the local ambient pressures.

The device is essentially a barometer, with moisture saturated air trapped in the body. The liquid level in the spout (and thus in the body) will change in response to changing atmospheric pressure. By looking at the level and rate of rise or fall of liquid in the spout or neck, one can predict weather.

Typically

Rising slowly ⇒ Approaching low pressure zone, and possibly a storm

Rising rapidly ⇒ Storm nearby + approaching

Bubbling out of spout ⇒ High intensity storm or tornado approaching or in area

Rapidly falling during a storm ⇒ Storm almost over

Holding steady at low level ⇒ Clear weather expected

The atmospheric pressure is different from the pressure in the bulb by ($\Delta h \rho g$), if interfacial tension is neglected.